EVALUATION PROGRAM
for
SECONDARY SPACECRAFT CELLS

ACCEPTANCE TEST

OF

GULTON INDUSTRIES, INC.

6.0 AMPERE-HOUR ADHYDRODE CELLS

prepared for
GODDARD SPACE FLIGHT CENTER

CONTRACT W11,252B

QUALITY EVALUATION LABORATORY
NAD CRANE, INDIANA

QUALITY EVALUATION LABORATORY
UNITED STATES NAVAL AMMUNITION DEPOT
CRANE, INDIANA

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SECONDARY SPACECRAFT CELLS

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QE/C 65-536 28 JULY 1965

PREPARED UNDER THE DIRECTION OF

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Enclosure (1)

REPORT BRIEF

GULTON 6.0 AMPERE-HOUR ADHYDRODE NICKEL CADMIUM SECONDARY SPACECRAFT CELLS

Ref: (a) National Aeronautics and Space Administration Purchase Order Number W11,252B
(b) NASA ltr BRA/VBK/pad of 25 September 1961 w/BUWEPS first end FQ-1:WSK of 2 October 1961 to CO NAD Crane
(c) Preliminary Work Statement for Battery Evaluation Program of 25 August 1961

I. TEST ASSIGNMENT BRIEF.

A. In compliance with references (a) and (b), evaluation of Gulton 6.0 ampere-hour Adhydrode Secondary Spacecraft Cells was begun according to the program outline of reference (c).

B. The object of this evaluation program is to gather specific information concerning secondary spacecraft cells. Information concerning performance characteristics and limitations, including cycle life under various electrical and environmental conditions, will be of interest to power systems designers and users. Cell weaknesses, including causes of failure of present designs, will be of interest to suppliers as a guide to product improvement.

C. Thirty cells were purchased from Gulton Industries, Inc., Metuchen, New Jersey by National Aeronautics and Space Administration (NASA). These cells are rated at 6.0 ampere-hours by the manufacturer and include the adhydrode or absorption hydrogen type auxiliary electrode.

II. CONCLUSIONS.

A. From the results of this test, it can be concluded that:

1. The ceramic seals of these cells, manufactured by Gulton Industries, Inc. are satisfactory as evidenced by no leakers out of the 33 cells tested.

2. The capacity of the cells was in the acceptable range of 6.75 to 7.35 ampere-hours.

III. RECOMMENDATIONS.

A. It is recommended that these Gulton Industries, Inc. 6.0 ampere-hour adhydrode cells be accepted on the basis of the acceptance test results.

RESULTS OF ACCEPTANCE TESTS

OF

6.0 AMPERE-HOUR ADHYDRODE NICKEL CADMIUM SECONDARY SPACECRAFT CELLS

MANUFACTURED BY

GULTON INDUSTRIES, INC.

I. INTRODUCTION.

A. On 1 December 1964, this activity began acceptance tests on 30 cells. These tests were completed on 16 June 1965.

II. TEST CONDITIONS.

A. All acceptance tests were performed at an ambient temperature between 23° C and 27° C at existing relative humidity and atmospheric pressure, and consisted of the following:

1. Phenolphthalein Leak Test.
2. Capacity Test.
3. Cell Short Test.
4. Immersion Seal Test.
5. Overcharge Test.
6. Internal Resistance Test of the Adhydrode.
7. Immersion Seal Test.

B. All charging and discharging was done at constant current (± 5 percent). Cells were charged in series but discharged individually.

III. CELL IDENTIFICATION AND DESCRIPTION.

A. Cells were identified by the manufacturer's serial numbers which were from 123 to 322 although not consecutively.

B. The 6.0 ampere-hour adhydrode cell (VO-6 H.S.I.) is rectangular in shape with an average height (base to top of positive terminal), length and width of 3.591, 2.089 and 0.812 inches respectively.

The average weight is 275.3 grams. The individual cell dimensions and weight are given in Table I. Figure 1 is a photograph of a Gulton Industries, Inc. VO-6 H.S.I. adhydrode cell.

C. The cell container or can, and cell cover are made of stainless steel. Both terminals are insulated from the cell cover by a ceramic seal and protrude through the cover as solder type terminals.

D. These cells, rated by the manufacturer at 6.0 ampere-hours, were supplied in a discharged (each with shorting wire) condition.

IV. TEST PROCEDURE AND RESULTS.

A. Phenolphthalein Leak Test.

1. The phenolphthalein leak test is a determination of the condition of the welds and ceramic seal on receipt of the cells. This test was performed with a phenolphthalein spray indicator solution of one-half of one percent concentration.

2. There were no signs of leakage on any of the 30 cells subjected to the leak test.

B. Capacity Test.

1. The capacity test is a determination of the cell capacity at the c/2 discharge rate, where c is the manufacturer's rated capacity, to a cutoff voltage of 1.00 volt per cell. The discharge was made after a 1-hour open circuit period following the 16-hour charge at the c/10 rate. A total of three capacity checks were made at this activity. The cells were discharged individually, but were recharged in series.

2. In order to gather data on the characteristics of the adhydrode, 51 ohms resistance was used between the adhydrode and the negative terminal for the first capacity check; 24 ohms was used for the second capacity check; and an open circuit or infinite resistance was used for the third capacity check.

3. Since complete capacity data, including adhydrode characteristics with the three resistance values, was not submitted by the manufacturer, it was not possible to compare the manufacturer's results with those of this activity. The individual cell capacities ranged from 6.75 to 7.35 ampere-hours for an average of 7.04 ampere-hours to 1.00 volt. The cell capacities together with the adhydrode characteristics are tabulated in Table II. Characteristic 2-hour rate discharge curves are shown in Figure 2.

4. Three cells were rejected during the capacity checks as the adhydrode was apparently shorted to the negative plate.

C. Cell Short Test.

1. The cell short test is a means of detecting slight shorting conditions which may exist because of imperfections in the insulating materials, or damage to element in handling or assembly.

2. Following completion of the third capacity discharge test, each individual cell was loaded with a resistor of value giving c/1 to c/5 discharge rate and allowed to stand 16 hours with the resistor acting as a shorting device. At the end of 16 hours, the resistors were removed and the cells were placed on open circuit stand for 24 hours. Any cell whose voltage did not recover to 1.15 volts or higher was rejected.

3. The open circuit cell voltages, 24 hours after removal of the shorting resistors, ranged from 1.17 to 1.21 volts for an average of 1.18 volts.

4. There were no rejects of any of the cells subjected to the cell short test. The voltage values for the 30 accepted cells are shown in Table II.

D. Immersion Seal Test.

1. The immersion seal test is a means of detecting leakage of a seal or weld. The test was performed before and after the overcharge test sequence to determine the presence and cause of leaks.

2. The cells were placed under water in a bell jar container. A vacuum of 20 inches of mercury was held for 3 minutes. Cells discharging a steady stream of bubbles were considered rejects.

3. There were no rejects in the 30 cells subjected to the immersion seal test.

E. Overcharge Test.

1. The overcharge tests were performed to determine the steady state voltage at specified rates. The test specified a series of constant current charges at c/20, c/10 and c/5 rates, for a minimum of 48 hours at each charge rate or until the increase of the "on-charge" voltage was less than 10 millivolts per day.

2. The cells were monitored hourly throughout the test. Charging was to be discontinued on cells which exceeded 1.50 volts while on charge. There was no need to remove any cells from the charging sequence.

3. The steady state voltage of each cell at the end of each 48-hour charge rate test is shown in Table II. Characteristic overcharge voltage curves are shown in Figure 3.

F. Internal Resistance Test.

1. This test was performed to determine the internal resistance of the adhydrode.

2. During the c/10 charge rate portion of the overcharge test; the voltage drop across the 51 ohm resistor connecting the adhydrode to the negative terminal was measured. The 51 ohm resistor was then shunted with a one ohm resistor for 5 to 10 seconds and the voltage drop across the two paralleled resistors (0.9808 ohms) was measured. The internal resistance of the adhydrode in ohms was calculated according to the following formula:

$$R = \frac{V1 - V2}{I2 - I1}$$

where V1 = voltage drop in volts across the 51 ohm resistor
V2 = voltage drop in volts across the 0.9808 ohm resistors
I1 = current flow in amperes through the 51 ohm resistor
I2 = current flow in amperes through the 0.9808 ohm resistors.

3. The internal resistance value for the adhydrode of each cell is shown in Table III. The values range from 3.29 ohms to 7.41 ohms.

TABLE I

CELL NUMBER	WEIGHT (GRAMS)	HEIGHT (INCHES)	LENGTH (INCHES)	WIDTH (INCHES)	CELL NUMBER	WEIGHT (GRAMS)	HEIGHT (INCHES)	LENGTH (INCHES)	WIDTH (INCHES)
125	276.0	3.590	2.104	0.821	151	274.8	3.595	2.085	0.812
129	274.3	3.592	2.100	0.812	152	275.5	3.585	2.087	0.812
130	276.2	3.587	2.090	0.812	153	275.0	3.587	2.088	0.812
131	275.7	3.587	2.087	0.812	155	276.1	3.587	2.087	0.812
140	275.6	3.595	2.087	0.814	157	275.8	3.587	2.087	0.812
141	274.8	3.600	2.089	0.812	158	277.2	3.590	2.090	0.812
142	274.8	3.597	2.090	0.812	159	276.0	3.592	2.095	0.812
143	276.1	3.590	2.085	0.812	161	276.0	3.580	2.087	0.812
144	274.0	3.591	2.087	0.812	162	276.2	3.584	2.087	0.812
145	276.0	3.588	2.087	0.815	163	278.7	3.590	2.090	0.812
146	275.4	3.588	2.090	0.812	207	279.8	3.596	2.085	0.812
147	275.6	3.590	2.093	0.812	209	275.8	3.590	2.089	0.814
148	277.0	3.590	2.085	0.814	320	279.2	3.590	2.090	0.812
149	277.5	3.592	2.087	0.812	321	281.5	3.600	2.093	0.812
150	274.5	3.600	2.083	0.816	322	279.0	3.585	2.090	0.812

TABLE II

CELL NUMBER	END OF CHARGE WITH 51 OHM RESISTOR		CAPACITY NO. 1	END OF CHARGE WITH 24 OHM PESISTOR		CAPACITY NO. 2	END OF CHARGE WITH NO RESISTOR		CAPACITY NO. 3	CELL SHORT TEST	c/20 OVERCHARGE			c/10 OVERCHARGE			c/5 OVERCHARGE		
											CELL VOLTAGE	THIRD ELECTRODE		CELL VOLTAGE	THIRD ELECTRODE		CELL VOLTAGE	THIRD ELECTRODE	
	Volts	Amps		Volts	Amps		Volts	Amps				Volts	Amps		Volts	Amps		Volts	Amps
125	0.42	0.0082	7.35	0.44	0.0183	7.20	0.91	0	6.60	1.20	1.40	0.54	0.0106	1.42	0.65	0.0127	1.45	0.77	0.0151
129	0.51	0.0100	7.20	0.51	0.0212	6.90	0.91	0	6.00	1.21	1.40	0.59	0.0116	1.41	0.69	0.0135	1.43	0.78	0.0153
130	0.47	0.0092	7.20	0.44	0.0183	7.05	0.90	0	6.45	1.18	1.40	0.52	0.0102	1.41	0.63	0.0123	1.43	0.72	0.0141
131	0.40	0.0078	7.26	0.38	0.0158	6.99	0.91	0	6.36	1.18	1.40	0.50	0.0098	1.41	0.92	0.0180	1.44	0.69	0.0135
140	0.46	0.0090	6.90	0.44	0.0183	6.75	0.90	0	6.36	1.19	1.40	0.40	0.0078	1.42	0.55	0.0108	1.44	0.69	0.0135
141	0.46	0.0090	6.90	0.42	0.0134	6.34	0.90	0	6.45	1.17	1.40	0.34	0.0067	1.42	0.48	0.0094	1.43	0.59	0.0116
142	0.45	0.0088	7.11	0.44	0.0183	6.99	0.89	0	6.66	1.19	1.40	0.41	0.0080	1.41	0.55	0.0108	1.43	0.65	0.0127
143	0.41	0.0080	7.14	0.37	0.0154	6.99	0.90	0	6.60	1.18	1.40	0.31	0.0061	1.42	0.47	0.0092	1.44	0.58	0.0114
144	0.44	0.0086	6.99	0.42	0.0134	6.96	0.89	0	6.54	1.17	1.40	0.36	0.0071	1.42	0.50	0.0098	1.45	0.58	0.0114
145	0.44	0.0086	7.05	0.39	0.0162	6.81	0.87	0	6.51	1.19	1.40	0.48	0.0094	1.42	0.60	0.0113	1.45	0.72	0.0141
146	0.44	0.0086	7.11	0.41	0.0171	6.96	0.89	0	6.69	1.18	1.40	0.37	0.0072	1.42	0.48	0.0094	1.45	0.61	0.0120
147	0.44	0.0086	6.84	0.42	0.0134	6.75	0.89	0	6.54	1.18	1.40	0.38	0.0074	1.42	0.50	0.0098	1.44	0.62	0.0121
148	0.46	0.0090	6.75	0.43	0.0179	6.54	0.89	0	6.30	1.19	1.40	0.39	0.0076	1.42	0.53	0.0104	1.44	0.63	0.0123
149	0.44	0.0086	7.29	0.51	0.0212	7.26	0.91	0	7.05	1.19	1.40	0.52	0.0102	1.42	0.65	0.0127	1.44	0.76	0.0144
150	0.42	0.0082	7.11	0.40	0.0165	7.05	0.91	0	6.90	1.19	1.40	0.37	0.0072	1.42	0.51	0.0100	1.45	0.63	0.0123

TABLE II (Contd)

CELL NUMBER	END OF CHARGE WITH 51 OHM RESISTOR		CAPACITY NO. 1	END OF CHARGE WITH 24 OHM RESISTOR		CAPACITY NO. 2	END OF CHARGE WITH NO RESISTOR		CAPACITY NO. 3	CELL SHORT TEST	c/20 OVERCHARGE			c/10 OVERCHARGE			c/5 OVERCHARGE		
											CELL VOLTAGE	THIRD ELECTRODE		CELL VOLTAGE	THIRD ELECTRODE		CELL VOLTAGE	THIRD ELECTRODE	
	Volts	Amps		Volts	Amps		Volts	Amps				Volts	Amps		Volts	Amps		Volts	Amps
151	0.43	0.0084	7.11	0.44	0.0183	6.96	0.90	0	6.66	1.18	1.40	0.40	0.0078	1.42	0.53	0.0104	1.44	0.62	0.0121
152	0.46	0.0090	6.75	0.42	0.0184	6.54	0.89	0	6.21	1.18	1.40	0.50	0.0098	1.42	0.60	0.0118	1.44	0.68	0.0133
153	0.45	0.0088	6.99	0.42	0.0184	6.84	0.90	0	6.69	1.18	1.40	0.37	0.0072	1.42	0.49	0.0019	1.45	0.61	0.0120
155	0.44	0.0046	7.20	0.33	0.0137	6.99	0.91	0	6.66	1.19	1.40	0.39	0.0076	1.42	0.52	0.0102	1.46	0.61	0.0120
157	0.53	0.0104	6.99	0.44	0.0183	6.75	0.90	0	6.39	1.19	1.43	0.43	0.0084	1.42	0.53	0.0104	1.40	0.64	0.0125
158	0.50	0.0098	6.99	0.43	0.0179	6.75	0.89	0	6.39	1.18	1.43	0.42	0.0082	1.42	0.54	0.0106	1.40	0.61	0.0120
159	0.50	0.0098	7.14	0.46	0.0192	7.11	0.89	0	6.81	1.18	1.42	0.45	0.0088	1.41	0.59	0.0116	1.40	0.69	0.0135
161	0.47	0.0092	7.14	0.42	0.0184	7.05	0.89	0	6.81	1.18	1.43	0.43	0.0084	1.42	0.54	0.0106	1.40	0.62	0.0121
162	0.46	0.0090	6.99	0.42	0.0184	6.81	0.95	0	6.45	1.17	1.42	0.43	0.0084	1.41	0.55	0.0108	1.40	0.65	0.0127
163	0.46	0.0090	6.99	0.42	0.0184	6.81	0.89	0	6.60	1.18	1.42	0.35	0.0068	1.41	0.48	0.0094	1.40	0.59	0.0116
207	0.47	0.0092	7.11	0.38	0.0158	6.81	0.89	0	6.36	1.19	1.41	0.48	0.0094	1.40	0.59	0.0116	1.40	0.67	0.0131
209	0.46	0.0090	7.20	0.37	0.0154	6.99	0.88	0	6.60	1.17	1.42	0.39	0.0076	1.41	0.51	0.0100	1.40	0.59	0.0116
320	0.45	0.0088	6.90	0.42	0.0184	6.15	0.91	0	5.76	1.18	1.40	0.43	0.0084	1.40	0.55	0.0108	1.40	0.61	0.0120
321	0.46	0.0090	6.75	0.43	0.0179	6.30	0.91	0	5.76	1.18	1.40	0.43	0.0084	1.40	0.55	0.0108	1.38	0.62	0.0121
322	0.48	0.0094	6.84	0.40	0.0167	6.51	0.91	0	5.85	1.18	1.40	0.43	0.0084	1.40	0.54	0.0106	1.39	0.61	0.0120

TABLE III

ADHYDRODE RESISTANCE

CELL NO.	OHMS	CELL NO.	OHMS	CELL NO.	OHMS
125	6.50	146	3.39	158	5.02
129	6.42	147	3.59	159	5.75
130	6.50	148	4.28	161	5.89
131	7.41	149	7.23	162	4.90
140	4.48	150	4.29	163	4.96
141	4.21	151	3.96	207	5.29
142	4.07	152	4.58	209	4.43
143	3.82	153	3.58	320	3.58
144	3.29	155	4.03	321	3.39
145	4.59	157	5.08	322	4.28

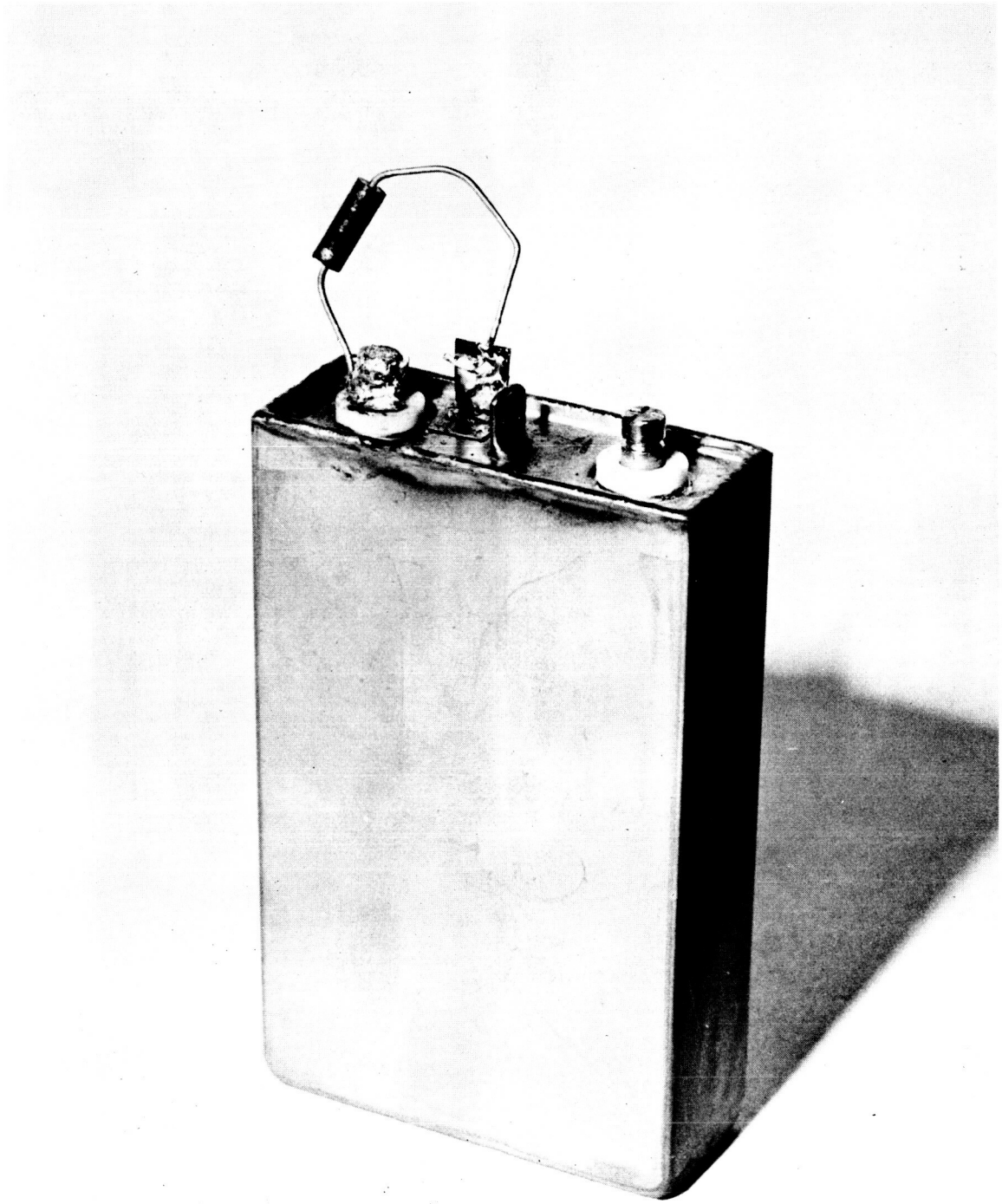
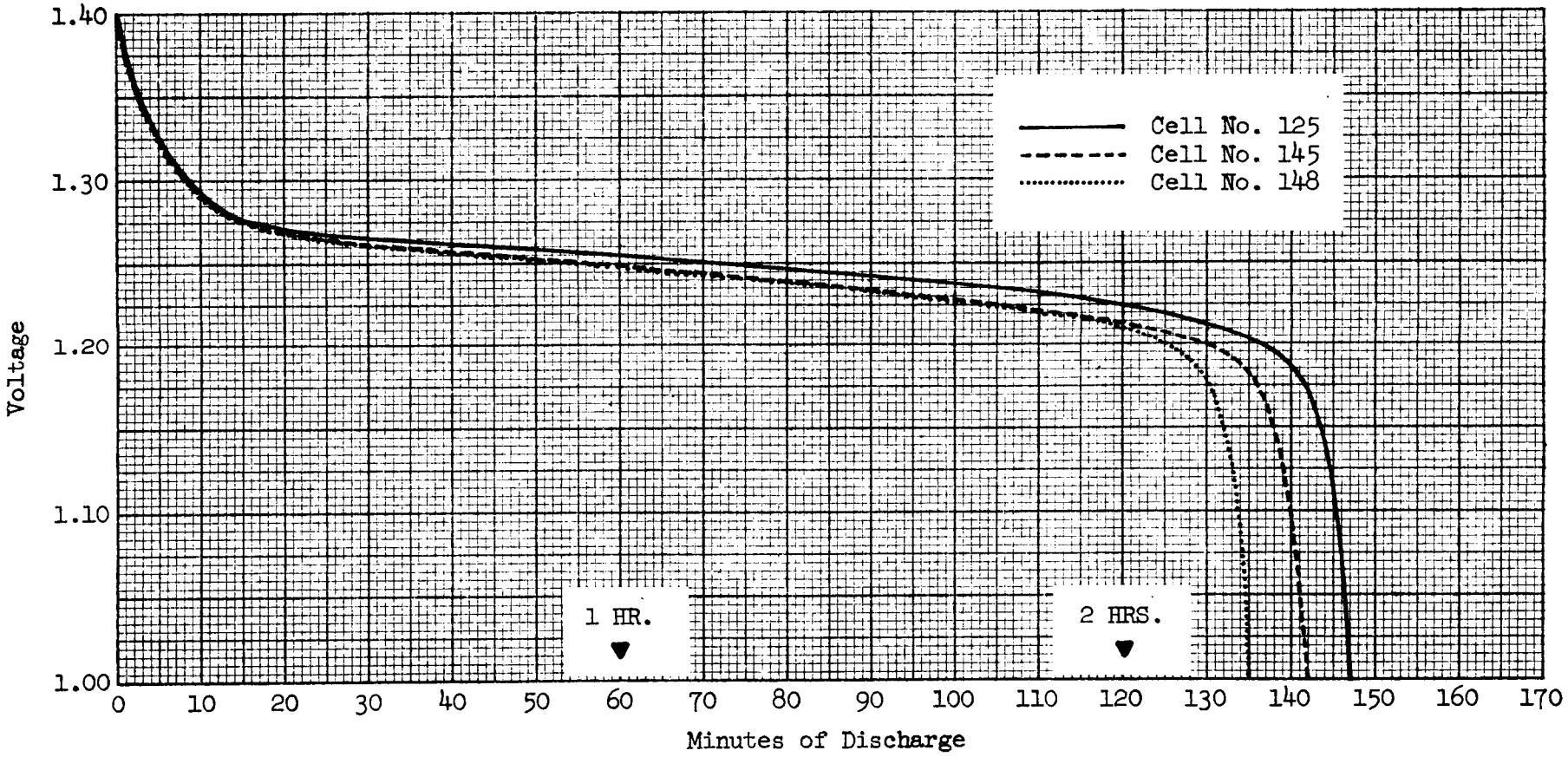


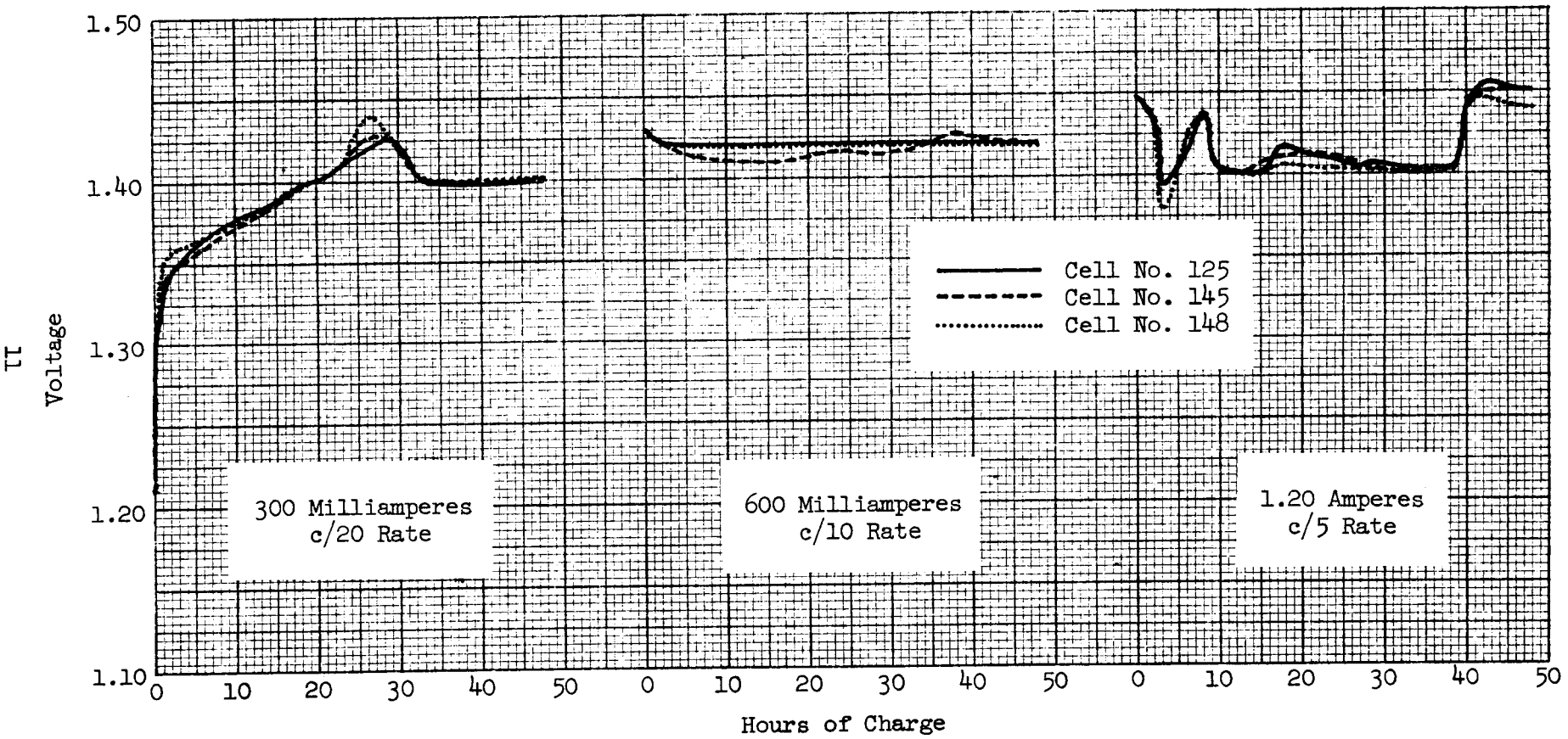
FIGURE 1



CHARACTERISTIC 2-HOUR RATE DISCHARGE

GULTON 6 AMPERE-HOUR ADHYDRODE NICKEL CADMIUM SEALED CELLS

FIGURE 2



CHARACTERISTIC 48-HOUR OVERCHARGE CURVES

GULTON 6 AMPERE-HOUR ADHYDRODE NICKEL CADMIUM SEALED CELLS

FIGURE 3

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